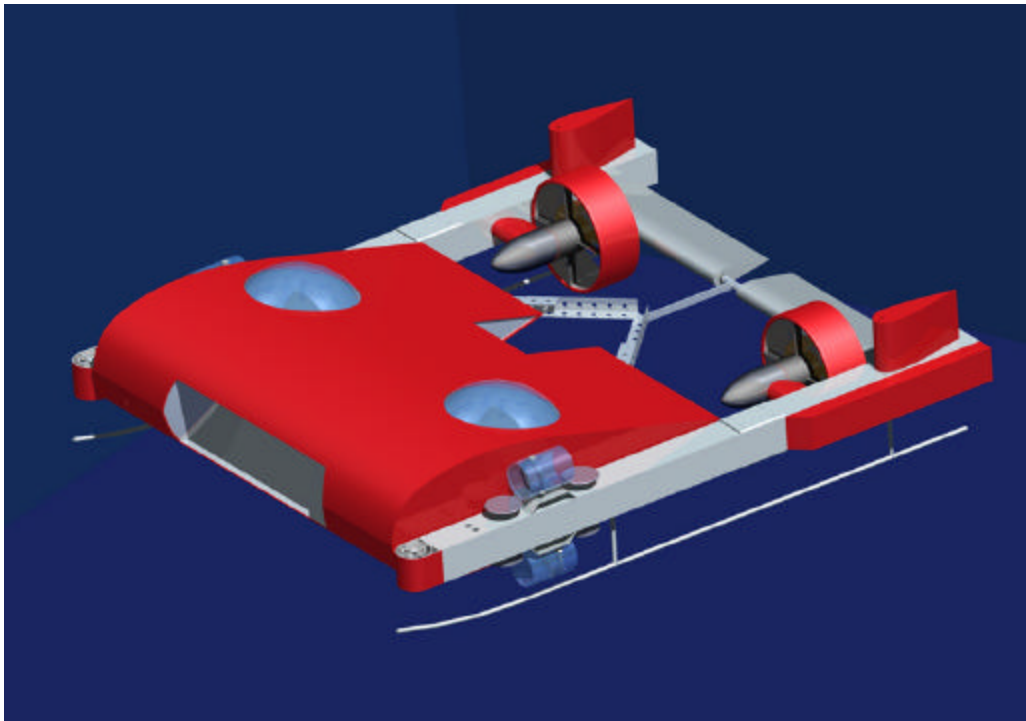


Autonomous Underwater Vehicle: Powered Glider



**Florida Institute of Technology
Department of Marine and Environmental Sciences
Ocean Engineering**

Design Team:
Todd Allen
Joseph Caldwell
Sean Kuhn
Seth Noyes

Abstract

The AUV Powered Glider is the future of underwater surveying. The glider opens up research possibilities in oceanography, geology, marine biology, and many more fields. This AUV Powered Glider provides a mobile platform that is controlled by a central computer. This computer can be programmed to allow the glider be tasked with missions of any length or type. The computer on the glider also provides the means to be configured with any kind of sensor, this allows it to do any number of things while on a mission even altering the mission based on sensor readings. The AUV Powered Glider provides endless opportunities for a number of different fields. With the glider's universal design and advanced computer system the AUV Powered Glider is the ideal vehicle for any underwater research.

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1.3. Glossary

AUV	Autonomous Underwater Vehicle
COLREG	Collision Regulations
CTD	Conductivity, Temperature, Depth Sensor
ESA	Endangered Species Act
GPS	Global Positioning System
GUI	Graphical User Interface
INS	Inertial Navigation System
MMPA	Marine Mammal Protection Act
NAV	Navigation
SBC	Single Board Computer
SONAR	Sound Navigation and Ranging
UV-VIS	Ultra Violet – Visual Light Spectrums

2. Introduction

2.1. Executive Summary

The AUV Powered Glider is an underwater vehicle that can lead to numerous papers and years of research. As a result we focused on the main systems and the considerations for future systems. We addressed the major objectives and obstacles to design a universal mobile platform that is ready to be controlled by an autonomous computer system. This platform is fully ready for operation at 4,000 meters water depth and can operate both in power and glide modes. The glider platform is also takes into consideration the placement and requirements for future systems. These systems range from new sensors, thrusters, servos, computers, and batteries.

The AUV computer is cutting edge technology that requires some of the most demanding programming out there. As a result we focused more on the platform aspect of the vehicle and have created a control board where a user can test all of the glider's current features. The glider will however be ready to accept the commands of an autonomous computer system when it's complete and will take the place of the operator.

2.2. Key Objectives

- Functional at 4,000 meters underwater
- Able to collect samples
- Operate self propelled
- Fully capable of gliding
- Platform for module sensors

2.3. Key Obstacles

- Limited Resources
- High Levels of Ambient Pressure at Target Depths
- Finding and Developing a long lasting Power Supply
- Planning for future Maintenance
- Developing emergency protocols
- Planning for future not yet invented sensors

2.4. Example Application Scenarios

The AUV Powered Glider is capable of doing a multitude of different missions. These missions range from all fields of underwater studies including seabed research and exploration. The AUV Powered Glider provides a mobile platform that can be equipped and programmed for the user's needs. This flexibility makes it the perfect tool for any kind of mission or task. Two of the main types of scenarios you could do are area surveying and specimen tracking. With area surveying you could set the AUV Powered Glider to hover, circle, or search in a grid pattern over a specific area and search for something in particular and/or record anything it does find. Another main type of mission scenario is specimen tracking. The AUV Powered Glider will have the ability to actively read the sensors instead of just archiving the data. This ability allows the glider to actively track any specimen, marine animal, or even track a chemical to its source.

2.4.1. Area Survey

The AUV Powered Glider's computer can be programmed to circle a pre-designated area or to work in a grid pattern over the area collecting sensor data and if desired the glider can even act on the data and investigate further.

The AUV Powered Glider can be equipped with numerous sensors for this type of mission. Some of the sensors you could equip the glider with are:

- Profiling Sonar
- Side Scan Sonar
- Hydrophones
- UV VIS Mass Spectrometer
- Digital imaging devices
- Many more...

The flexibility of the AUV Powered Glider makes it the perfect platform for surveying and monitoring subsurface ocean conditions. Uses include:

- Surveying future oil drilling site
- Monitoring pollution affects over time
- Cataloging all local marine life
- Many more...

2.4.2. Specimen Tracking

The AUV Powered Glider's already built in AUV computer can be programmed to actively collect and use sensor readings instead of just recording and archiving them. Usually when an underwater vehicle collects data it just stores it on a hard drive or some sort of flash memory for future review. In this instance you could feed a sensor

directly into the navigation part of the glider's computer and adjust your course based on the sensor readings.

The AUV Powered Glider can be equipped with numerous sensors for this type of mission. These sensors include but are not limited to:

- UV VIS mass spectrometer
- Aqua III fluorimeter
- Hydrophones
- Many more...

The combined power of the onboard computer and the glider's sensors give the AUV Powered Glider the ability to investigate, track, and follow things like:

- Large marine animals
- Algae Blooms
- Chlorophyll Sources
- Chemical Spills
- Many more...

3. Background

The concept of the AUV Powered Glider called for an independent vehicle capable of enduring a depth of four thousand meters and being able to carry a variety of sensors down with it for an extended period of time. The development of this concept looks at the current AUV gliders to determine how to conserve power for longer mission duration. The concept also needs to bring the variety of sensors, maneuverability, and depth rating of the more common AUVs.

3.1. Other AUVs

3.1.1. AUV Gliders

The purpose of an AUV Glider is to collect information for an extended amount of time. To be able to operate for this duration the gliders rely on expending as little power as possible. To minimize their power usage these gliders have no thrusters for propulsion. The only power drain they have is for their sensors, computer, and buoyancy control. There are currently three such gliders the University of Washington's Seaglider, Bluefin's Spray Glider, and Webb Research Corporation's Slocum Glider. The gliders are a slightly altered torpedo shape. The gliders use their buoyancy control system to gain their

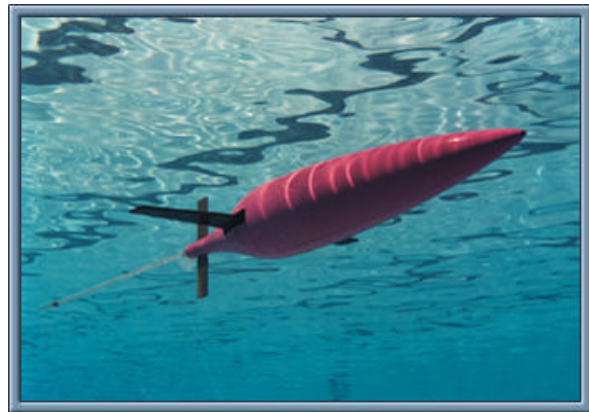


Figure 3.1: Seaglider (Photo Courtesy of University of Washington, Applied Physics Laboratory)



Figure 3.2: Spray Glider (Photo Courtesy of Bluefin Robotics)

initial ascending or descending motion. The gliders then alter the angle of their fins to turn a portion of their vertical motion into a horizontal motion. This gives the gliders a saw tooth pattern to follow through the water column. While



Figure 3.3: Slocum Glider (Photo courtesy of Webb Research Corp.)

moving through the water column these gliders have a CTD, fluorimeter, and optical backscattering sensors to take measurements with. At the peak of the saw tooth pattern, when the gliders are at or near the surface, they are able to send and receive information via a satellite antenna. The gliders transmit the data they just collected and are able to receive any changes to the mission it was sent out to do. All of these gliders rely on pumping water into and out of a space. This type of system limits the depths these gliders could reach to between a thousand and fifteen hundred meters. Despite the limit in depth the gliders are able to operate for months at a time since the power drain on their batteries is only a minimal draw needed by the sensors and computer. (Bluefin) (Webb) (Light)

3.1.2. Deepwater AUVs

There are several deepwater AUVs. Current Deepwater AUVs are built for a specific mission to be repeated. The majority of these AUVs deal with ocean floor surveying. The use of these AUVs is more based on the inconvenience of a tether long enough to reach where these AUVs operate rather than the



Figure 3.4: ABE (Photo courtesy of Woods Hole Oceanographic Institute)

timeframe they operate in. The time limit for these AUVs is dependent on their battery supply and how quickly the thrusters, sensors, and computers drain them. Several of the deepwater AUVs that are currently in use are Echo Ranger from Boeing, Fugro N.V. and Oceaneering International, Inc.; Hugin 3000 from Kronsberg Maritime; and ABE from Woods Hole Oceanographic Institute. The Echo Ranger and Hugin 3000 both are rated to a depth up to three thousand meters. (Boeing) The Hugin 3000 unlike the Echo Ranger, which is designed only for ocean floor surveying, can be outfitted with whatever sensors their customer wants installed. (Kronsberg Maritime) ABE is different from the other two by being able to reach a depth of five thousand meters, but is similar to the Echo Ranger in its sensors are for ocean floor surveying as well. ABE uses a weight release system to control its buoyancy. ABE would be deployed and use minimal maneuvering to get close to its target location. At this location ABE would release several weights to make it neutrally buoyant. ABE would then carry out its assigned surveying. At the end of its surveying ABE would release a last set of weights to return to the surface. At the last weight release ABE would have expended the majority of its battery power which depending the level of detail used in the sensor payload could be between fifteen and thirty hours. (Woods Hole Oceanographic Institute)

3.2. Current Technology

3.2.1. Control Systems

The control systems used in an AUV is all tied into the software operating the various equipment in the AUV and handling the independent navigation of the AUV. This software would be on an onboard computer. In order to properly navigate the computer would need to take input from several sensors aboard an AUV. These sensors would allow for an approximation of the position, direction, speed, orientation, and location of nearby objects. The computer would use this information to follow a pre-

determined course as closely as it was capable of and decide to alter the course if needed to avoid something unforeseen. The accuracy the computer will be able to follow this will depend on the error associated with the sensors and calculations used. The effectiveness of any control system would be in how small the errors it generated from calculations and sensors are. The sensors that would be needed to plot the position, course, speed, and object avoidance are inertial sensor, gyro compass, forward and downward facing sonar, a GPS receiver, and a pressure sensor. (Wood)

3.2.2. Depth Survivability

The current technology to survive the pressures of the deep ocean requires either no contained gases or pressure housings. These restrictions create two problems for vehicles, the vehicle's buoyancy and how to house electronics safely. The buoyancy problem requires either a pressure housing large enough to provide enough excess buoyancy for the vehicle to float or a material less dense than water and strong enough to have little deformation with the pressure change. A material that meets the criteria of being less dense than water and strong enough to withstand the pressure is the syntactic foam made by Syntech Technologies, Inc. This material is a foam with small glass beads embedded in it. The beads give the strength the material needs while the foam gives the added volume. The air filled pressure housing also solves the problem of housing electronics safely since an air filled area would be ideal to house a computer or other circuitry. Housing that meet these conditions are the Benthos or Vitrovex glass spheres. These spheres rely on the ambient pressure to strengthen the seal made by the two hemispheres of each sphere. Since the glass is thick enough to withstand the pressure up to certain depths these spheres hold air well up to their specified depth. The only electronics that would not be able to be held by these spheres are motors, since they require a shaft going out to what they move. The housings for these can be done either with sealed pressure housing designed to house the motor or a housing filled with a non-conductive oil to allow the motor to spin without corrosion and shorting sensors.

The fluid filled housings would also require a tube extruding from them to allow space for the fluid to compress to equalize the pressure inside the container with the exterior pressure. (Wood)

4. Prototype Model

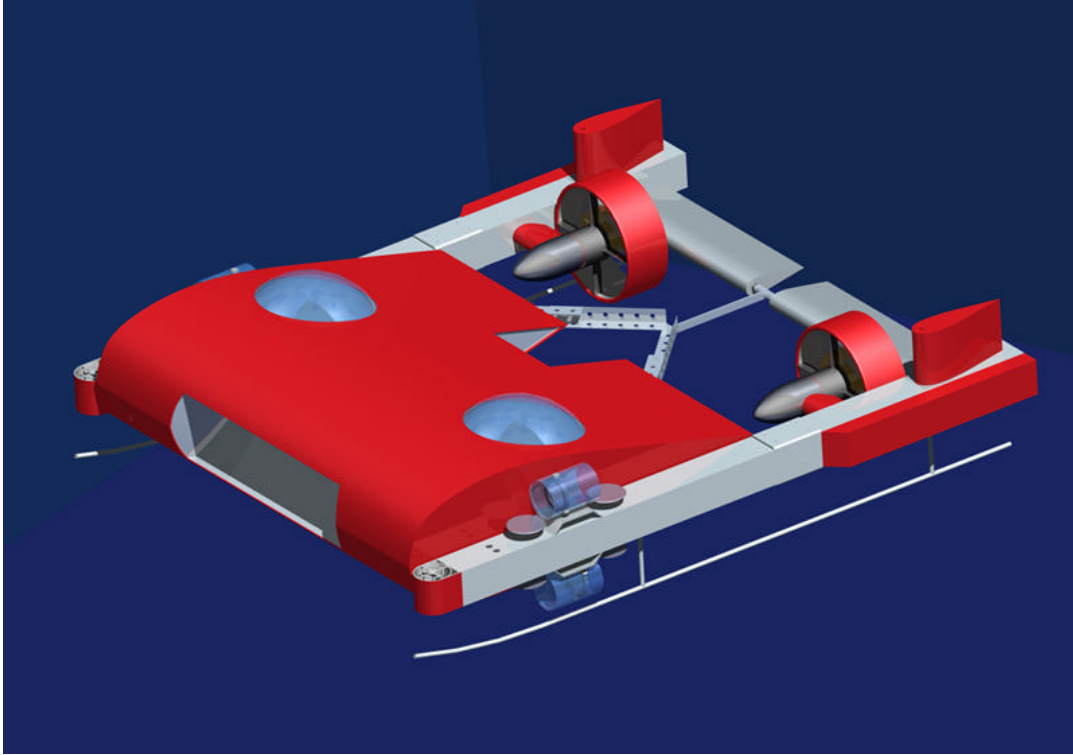


Figure 4.1: Prototype AUV Powered Glider Rendering

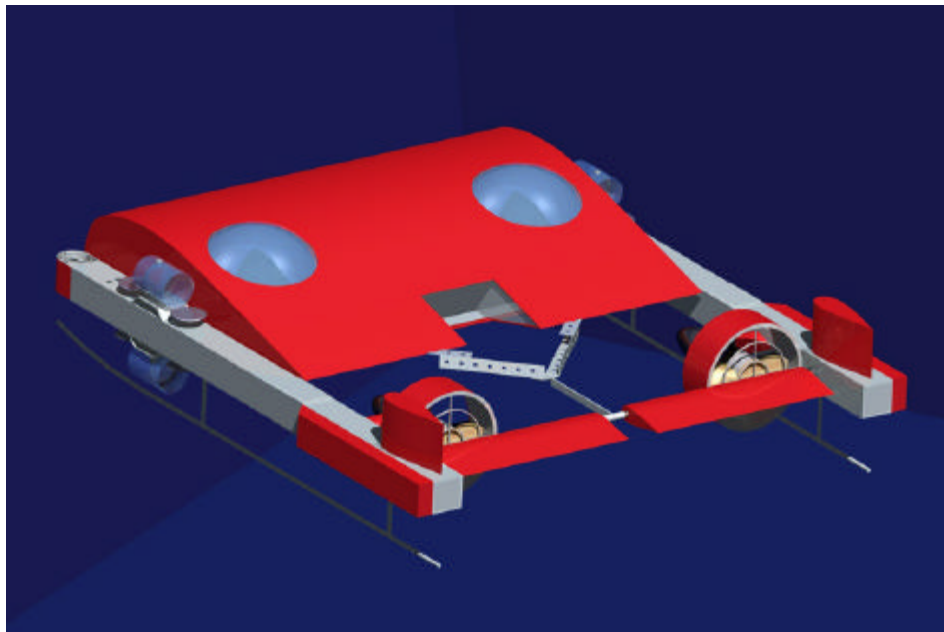


Figure 4.2: Prototype AUV Powered Glider Rendering

4.1. Design

The design of the AUV Powered Glider can be split into three main sections. The structure, central electronics, and the scientific aspects are all essential parts to the design of the glider. The structure includes the physical body and frame of the glider, which holds everything together. The central electronics include everything from the control boards to the motors and servos. And the scientific aspect includes everything from sample containers to most sensors.

Prototype AUV Powered Glider Specifications		
Running Properties		
Property	% Running Time	Value
Max Speed (Vmax):	5%	2.0 m/s
Endurance (powered):	20%	2 hours
Endurance (glide):	80%	8 hours
Dimensions		
Property	Value	
Vehicle Width:	62.5 inches (66.5 inches at flares)	
Vehicle Length:	76 inches	
Vehicle Height:	20 inches	

Table 4.1: Prototype AUV Powered Glider Specifications

4.1.1. Structure

The main structure of the AUV Powered Glider is composed of four main parts. The four main parts of the structure are the aluminum beam, the fiberglass hull, the oil filled housings, and the instrumentation spheres. Each one of these parts are vital to the operation of the AUV Powered Glider and each one requires great care in both their construction and usage.s

4.1.1.1. Aluminum Frame

The aluminum frame makes up the bulk of the structural support for the glider. The structural support frame consists of two 4" x 4" aluminum beams that are 1/8" thick and made of T6063 aluminum. Attaching these two beams together through the beam is two additional support beams that add rigidity to the overall glider and lightening the load on the fiberglass hull.

The two side support beams themselves are not sealed so they do not have to withstand the pressure. The beams provide the mounting points for several key features of the glider. The motors, ailerons, sample containers, rails and even the main foil are directly mounted to the beams. The beams also contain a joint near the back of the main foil where the two halves of the beam can be unbolted. This allows the glider to be split into smaller sections that make it both easier to store and to transport.

4.1.1.2. Fiberglass Hull

The main fiberglass hull is made to the shape of a foil. The hull was constructed using a foam mold that was machined. The mold was made out of General Plastics 6700 aircraft grade modeling foam and machined at VectorWorks Marine in Titusville, FL. The fiberglass hull is mounted directly to the two side support beams as well as the two support cross members that pass through the main foil. The fiberglass hull holds many of the features that are essential to the glider. Contained within the glider is the power supply, instrumentation spheres, syntactic buoyancy foam, trim ailerons, specimen collector, and the weights for both the buoyancy control and to simulate the future sensors.

4.1.1.3. Oil Filled Housings

At depths of 4,000 meters underwater, the water pushes in at a pressure of around 6,000 psi. Such a high pressure puts a very high demand on the materials and parts being used. In this case if all the parts were made of materials and material thicknesses that could withstand the high pressure both the weight and the cost would grow exponentially. An efficient solution to this problem is to fill all of the housings with non-conductive oil such as mineral oil, more specifically transformer oil. This oil is usually used in capacitors and transformers. It provides an insulating barrier between power feeds and won't short the circuit like seawater. The housing or part will be assembled inside an oil-filled bucket, minimizing the possibilities of air bubbles. Attached to each housing will be a pressure tube that will help equalize the pressure outside and the pressure inside the container so the housing walls won't have to withstand the force of the pressure.

4.1.1.4. Instrumentation Spheres

The AUV Powered Glider uses two 17" glass instrumentation spheres. While different manufacturers make the two spheres, they do contain very similar specs and identical sizes. Both of these spheres also have pressure release valves for reopening them and multiple ports for cables to pass through for wiring. These spheres are the only part of the glider that contains air and is the only part that has to directly withstand the 6,000psi of water pressure pushing in on it.

The first sphere is made by Benthos Inc, and is model number 2040 -17H. It has a 17" outer diameter and weighs in at 39lbs. This gives the spheres a net buoyancy of 56lbs assuming they are empty. The Benthos sphere has been tested at depths of 6,700 meters. The Benthos sphere is also equipped with two ports for cables to pass through the sphere. (Benthos)

The second sphere is made by Victrovex and is the 17"/14 (standard) model. It also has a 17" outer diameter and weighs in at 38.14 lbs with about 61.13lbs of buoyancy. This sphere is also rated for depths of 6,700 meters. The Victrovex sphere also has three ports for cables and another port for a pressure sensor. (Vetrovex)

4.1.2. Central Electronics

The central electronics onboard the prototype model will be simple enough to be cost effective, yet complex enough to support the project goals. Working with these criteria it was prudent to choose a series of microcontrollers to adequately run operations on the AUV. PIC microcontrollers provide a very cheap, yet very programmable, system that can easily be designed for and expanded in the future. In addition microcontrollers have better resources for handling motor and servo control versus a standard computer. Because the prototype model will be tethered and human controlled, the priority lies in making a functional system. A functional system is a direct translation from the control boards to the motors and servos onboard the AUV. However, when the time is appropriate the human element could be removed, and simply match the computers output to that of the original control board and the computer will no be able to control the AUV.

4.1.2.1. Onboard Controller

The onboard controller will be one or more PIC (PIC18F) microcontrollers. They utilize a very simplistic programming language (i.e. PICbasic). The microcontrollers have onboard memory for programs and data. Each PIC has three programmable 8-bit input/output connections. We chose to use the PIC microcontrollers due to economical constraints. We were able to get sample chips from

the manufacturer of the PIC microcontroller, instead of buying a single board computer (sbc).

4.1.2.2. Control Board

The main control board for the prototype model will be a very simplistic control station with two joysticks and various toggle switches. The two joysticks will control the port and starboard systems respectively. These systems include the main thrusters, the rudders, and the main aileron. Each joystick will also be configured such that the main trigger will turn the main thruster on forward, and the top trigger will turn the main thruster on in reverse.

Further, the toggle switches will control various other parts of the AUV. Toggle switches are good to use in on/off scenarios. Each collector has two doors and a screen (which is reversible). Opening/Closing of the doors, and the rotation of the screen are all examples of on/off scenarios. Other points that the toggle switches will be used for is the lights, the camera, and the weight release system.

Our reasoning for going with this design is ease of use, economical, and fits with the other electronics. Having more of a control station versus a single remote control will allow for more than one operator, one controlling the steering while the other controls the remaining systems. On the economical side it is far cheaper to buy a couple joysticks and some toggle switches than a multi-channel remote control. And since we are planning to use the PIC microcontrollers on the prototype model, we can easily use a PIC microcontroller to accept input from the control board and pipe it to the other PIC microcontrollers on the sub using a very simple RS-232 serial connection.

4.1.2.3. Recovery System

The recovery system we are planning to use will be two fold. The first will be a high intensity light on an extended arm. The second will be a radio beacon, which can easily be tracked by a radio direction finder. The light will be mounted on a swing up arm so that at surface level the light is visible.

In the event of a control system failure the arm will be released and swing upward, in addition the radio beacon will be turned on. The entire recovery system will be self-contained having its own batteries and electronics pressure sealed. This is to ensure that a power failure in the rest of the AUV will not interfere with the recovery system.

The overall reason for this design is to allow for multiple recovery techniques as well as provide a fail-safe system, so that the AUV doesn't become unrecoverable.

For lifting the vehicle onto the research vessel there are four lifting points, one on each corner of the vehicle, requiring a four-point harness system. Each lifting point consists of a bolt running vertically through the side beams with an eye at the top. Together, the lifting points can support the weight of the vehicle with a factor of safety.

4.1.2.4. Main Thrusters

In the prototype model the main thrusters will be controlled by the two triggers on the joysticks. The main trigger will engage the main thruster in forward, while the top trigger will engage the main thruster in reverse. Thus the requirement for power will be a simple H-Bridge. An H-Bridge is an electronic device that allows for the reversing of polarity at the device. This will allow the computer to control the polarity of the signal to the motor, and thus control its direction. The motors we chose for the main thrusters are 12V and draw nominal amperage of 55A.

4.1.2.5. Servos

Early in the design we had initially thought of using stepper motors to control various devices on the AUV. These devices were: the rudders; the ailerons; the collection screens, the main screen. While stepper motors are fairly common place they generally require a number of pin-outs to be available on the microcontroller. In order to avoid the high pin count we decided to instead go with pulse width modulated (pwm) servos. Servos require a single pin-out from the microcontroller and a power feed. The major drawback in choosing servos is that they are not 360 rotating. However, we analyzed the systems that would require a servo this was not a requirement. Thusly, the various systems originally designed to use stepper motors for control have all been switched to using servos.

4.1.2.6. Power Management

The original design is for a fully autonomous AUV, thus no tether for control or power. However, due to battery cost the prototype will use a tether to feed its power need. The main thrusters and vertical thrusters will run on a 12V power system. While the remaining components will run a 5V system, that will down-converted from the 12V system. Thus, only one 12V line will be needed to power the AUV.

4.1.3. Scientific

Since the AUV Powered Glider is a scientific vehicle, it will be equipped with several instruments and sample collecting devices. These unique devices were developed specially to suit this vehicle and are used to collect either water or specimen samples on the vehicle are referred to as the sample containers. Most of the instruments included on the final production model vehicle will not be part of the prototype. They

will, however, be simulated as explained later in the section titled “Simulating Future Sensors.”

4.1.3.1. Prototype Sample Containers

The sample containers for this AUV Powered Glider are there to allow the researcher to collect both water and small specimen samples from many depths. The prototype model has four of these containers, one mounted on the top of each beam and one mounted on the bottom of each beam. Each container is set up to be activated independently. When triggered the sample containers would rotate the screen inside from being parallel to the direction of motion to perpendicular to it. After a set amount of time after this rotation occurs, the time is dependent on what the researcher wants, the two doors would release closing and sealing the containers. To obtain the sample the researcher would then have to remove the container by unhooking the nylon strap holding the container down then moving pulling it off the box being careful

The containers are made of clear tubing to allow the researcher to view the contents before opening the container. The tubing for each container is four and a quarter inches in diameter, an eighth of an inch thick, and six inches long. The tubes have three six tenths of an inch diameter holes cut into them, two vertical and one with its axis offset by forty-five degrees. The holes are two

inches back from the front of the container. These holes allow for the pivot points and stopper for the rotating screen in each container. Each hole is lined with a rubber seal to allow the container to be watertight. The pivot points and stopper are made of a half-inch diameter aluminum rod that is .95 inches long. The interior portions of the pivot

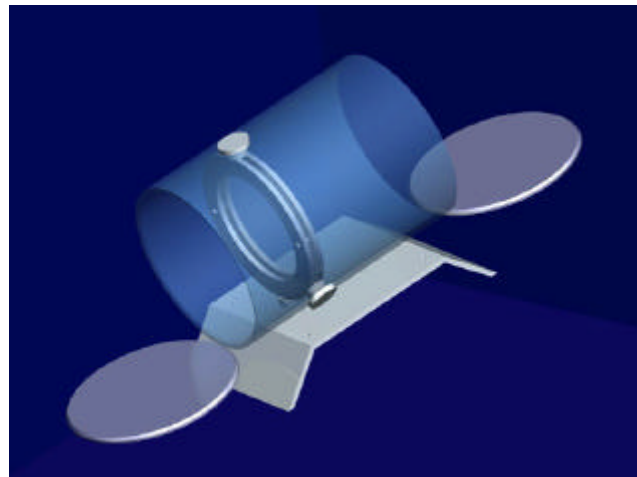


Figure 4.3: Prototype Sample Container

points and stopper have a half-inch by half-inch section removed parallel to the side of the rod going in by .4375 inches. This cut is for the screen to fit into. The top pivot point and stopper have an eighth of an inch thick and three quarters of an inch diameter head on their exterior portion to keep them attached to the tube. The bottom pivot point has an eighth of an inch thick quarter inch square keyed to the connector attached to the servo. The screen is held in place by 2 thin aluminum plates. One plate is mounted to the pivot points and the other is pressed against both the mounted plate and the screen by thumbscrews. The plates are rings with a 3.8 inch outer diameter and 2.8 inch inner diameter. The plates are 3.8 inches to give them room to be able to rotate freely rather than be completely up against the edge of the container. The plates have two eighth of an inch holes cut opposite of each other 1.65 inches from the center of the rings. The screens are replaceable so that a variety of gauges can be used to collect what the researcher is interested in. Each screen has a circular shape that is 3.8 inches in diameter with the top and bottom quarter inch removed. There also are 2 eighth of an inch holes cut into the screen a quarter inch from the left and right edges for the thumbscrews to pass through. The doors to the sample container are eighth of an inch thick aluminum plates, the edges have been beveled to allow for a rubber seal to be attached to them to seal the container when closed. The door and rubber seal together are 4 inches in diameter. The doors are closed by a mouse trap spring attached to the tube and outside of the door. Each door is held open before it needs to be deployed by an arm of a servo. The servo holding the door closed is a HS-125MG slim wing servo made by Hitec RCD USA, Inc. The sample containers rest on a trapezoidal platform made an eighth of an inch thick aluminum. The box is one and one eighth inches high, has a four inch long and three and a half inch wide top, the two diagonal pieces extend down at a forty-five degree angle. The top portion of the box has an eighth of an inch diameter hole cut into each of the four corners a quarter of an inch from each side. These holes are used to bolt the box to the side beams of the aluminum container. There is another hole .6 inches in diameter centered one and three quarters of an inch from the side of the box and one inch from the front of the top portion. This hole is lined with a rubber seal to reduce friction from the rotating connector that goes through

it. The connector is made out of the same half-inch diameter aluminum rod as the pivot points and stopper. The connector is 0.225 inches long and has an eighth of an inch deep quarter inch square hole cut in the top to allow the bottom pin of the container to connect to it. The servo this connector is mounted to is a HS-55 standard feather servo made by Hitec RCD USA, Inc. On the bottom of the box is a nylon strap that loops over the sample container to hold it down.

4.1.3.2. Simulating Future Sensors

Many sensors needed for the final production model will not be present on the prototype AUV Powered Glider. The sensors not present, however, will be simulated in the prototype.

Most of the future sensors that will be used on the final production model AUV Powered Glider will be represented in the form of weights, equivalent to the weights of the actual sensors, on the prototype model. The placement of these weights will be representative of the locations of the actual sensors of the production model. This will shift the center of gravity of the prototype close to that of the actual production model. Also, it will add to the overall weight of the vehicle affecting the overall buoyancy of the vehicle when it is submerged.

Below is a table of the values of the average weights in air and in water of some of the instruments that may be included in the final production model. The Inertial Navigation Unit must be contained in one of the glass spheres, so its weight in water is irrelevant. Its weight in air, however, was added to the total average weight in water.

Average Sensor Weight Specifications		
Sensor Type	Average Weight in Air (lbs)	Average Weight in Water (lbs)
CTD	7.63	4.26
Fluorimeter	8.27	5.16
UV VIS Spectrometer	7.93	1.58
Object Avoidance Sonar	3.61	1.70
Bottom Profiling Sonar	6.26	2.98
Hydrophone Array	14.83	9.25
Inertial Navigation Unit	18.46	-
Total Weight	66.99	43.39

Table 4.2: Average Sensor Weight Specifications

4.2. Construction

The construction phase of this project is a long and sometimes tedious process. During this process you are converting the plans and theory into an actual vehicle. This often results in numerous problems ranging from manpower to a part's fit. Some of the main construction obstacles we came across were:

- Manufacturing delays on the syntactic foam at Vectorworks Marine Inc.
- Material and parts arriving with dimensions outside stated tolerances.
- Servos from Hitec RCD not arriving with horn in specified position.
- Lack of sufficient skilled labor. Several times one more person would have helped in the machine shop since you have to work in groups of two or more at the machines.
- Then of course like every other project funding is always an obstacle.

4.2.1. Sub-Assemblies

The construction of this project was separated into several smaller sub-assemblies. These sub-assemblies allowed us to more efficiently allocate resources and organize the order of construction. Some of the main sub-assemblies include but are not limited to the main hull, buoyancy foam, side beams, bottom rails, servo boxes, ailerons and rudders, aileron coupler and camera mount, and the main thruster.

4.2.1.1. Main Hull

The main foil of the glider was used to hold both the main syntactic foam blocks and instrumentation spheres. The structure of the main glider revolved around creating a fiberglass shell in the desired size and shape that had an embedded support to maintain the integrity of the glider.

The construction of the main foil started with the machining of the molds at Vectorworks. This was carried out by first epoxying the set of three blocks used for one mold to a sheet of plywood. The blocks and sheet were then screwed onto Vectorworks' five axis cnc milling machine. The cnc machine proceeded to cut the foam blocks in the pre programmed path to cut out the necessary shape. This process was then repeated for the second mold. After the molds were machined they required some minor sanding to remove ridges left in the foam from the machining process. After the molds were sanded and obtained the desired shape of the glider the needed to be prepared for their fiberglassing. This was accomplished by coating the surfaces of the mold that were to be fiberglassed in epoxy. This was done using a foam brush to apply the epoxy over the foam. The epoxy was then given 12 hours to cure. After the epoxy was cured a second layer was applied and allowed to cure. This layer was then sanded with a 220 grit sandpaper. This was followed by another layer of epoxy and sanding and a last finishing layer of epoxy. This completed the molds for the main hull. The last step in preparing the molds was to add the mold release agents. We went with

the combination of PVA, paste unbuffed paste car wax and hairspray as our releasing agents. We applied 4 coats of the PVA to the molds we were going to fiberglass. The coats were done in 4 sections, one for each side, the front region and the remainder of the glider. Each section was done while having the mold propped up to have as close to a flat surface as possible. Each coat of each section was allowed three hours to dry. After the PVA had dried the Meguiar's Gold Class Paste Car Wax was applied over the surface. After this application a thick layering of Rave 4x Mega Hair Spray was applied. With this the mold was ready to be fiberglassed. The fiberglassing was done by first cutting the size strips of fiberglass being used. The actual fiberglassing was carried out by first applying a good amount of epoxy over the area the fiberglass strip is to be placed over. The strip would then be laid over the epoxy and dabbed into place with the brush being used for the epoxy. The next strip would be placed halfway over the first strip. This method was replicated for each and every strip used with sufficient dabbing to remove air bubbles and stick the strip to the mold's shape. The layers of fiberglass were done first a vertical pass, followed by a horizontal, then a diagonal, and lastly a long vertical layer. After the fiberglass had cured for twelve hours the shell was popped out by slowly prying it up from the excess over the edges of the mold and pulling small increments out at a time. Removing the shell caused damage to the corners of the mold. This problem was solved before the second shell made by clamping the corner in place and applying epoxy on the crack. After this epoxy had cured the exterior of the mold several fiberglass strips applied to add extra support to the front corners. The second shell was prepared in the same manner and the fiberglassing was done in much the same manner up till the completion of the second layer. When the second layer was done fiberglassing was stopped to determine the sizes of the support beams being embedded into the second shell, which was the bottom shell. We lined up to rectangular aluminum plates and made a diagonal cut to allow the piece to better fit roughly an inch below the top surface of the foil. Next the cross support was constructed. An extended 'L' piece was cut to fit across the foil and two other sections were cut out to be used as vertical supports. The vertical supports has a section of one of the sides of the 'L' shape removed to allow for the other section to be

bent to create a corner piece. The cut section was bent using a cement block and a mallet by repeated hitting the piece that was being bent till it moved to the desired shape. The support pieces were then lined up in the shell being worked on to see if they would fit in as was required. The cross support required more fiberglass built up underneath it to have a flat surface. The supports were fiberglassed into the shell by first clamping the side aluminum plates onto the mold and fiberglassing over the unclamped sections. Extra fiberglass was then put down along where the cross support was to go to create a level surface for it. The beam was then placed on this and fiberglassed down. With the excess fiberglass built up on the sides the center of the beam needed to be held down while fiberglassing. To minimize the time needed for someone to hold the beam down so as not to create an air bubble a heat gun was applied to the curing fiberglass to speed up its timing. While this fiberglass was curing the third layer was applied followed by the fourth layer. After the fourth layer cured the shell was then popped out originally by the same method but required the use of small two by two parts to pry out the shell. After the shells were popped they were trimmed with a dremel to get them to closer the desired shape. The holes for the instrumentation spheres were also trimmed out. After trimming the inside of the shells were sanded with a 220 grit sandpaper to smooth out the edges left by the fiberglass strips. Following this two holes were drilled to both the cross support and vertical supports together. These holes then had a nut and bolt put through them and siliconed into place. The shells were then given faired to smooth out the small imperfections in the fiberglass. This was done by sanding the exterior with a 120 grit sandpaper, cleaning the resulting dust off with compressed air and damp rags, and applying epoxy with the 410 Microlight Fairing Filler to the visible holes. This process was done twice followed by the final sanding and cleaning before being painted by Maaco. After we received the painted shell back the final part involving the shell was to drill holes for bolts into the aluminum side beams and to bolt the shell into the aluminum side beams.

4.2.1.2. Buoyancy Foam

The buoyancy foam is located both inside the main hull, inside the side support beams, inside the rudders, and inside the ailerons. While we will talk about the main hull and side support beams now, the ailerons and rudders construction will be discussed later.

The main foil is composed of a relatively thin fiberglass shell that is not capable of withstanding the pressure at depths of 4,000 meters. As a result, early in the design it was decided to use syntactic foam blocks to fill the main part of the hull. This syntactic foam is capable of both withstanding the pressure at these depths and provides buoyancy for the vehicle. The syntactic foam is about 38 lbs per cubic foot so to figure out how much buoyancy the foam provides you take the density of sea water which is about 64.1 lbs per cubic foot and subtract the density of the foam to get 26.1 lbs of buoyancy per cubic foot.

In the main foil the syntactic foam was split into six blocks for ease of manufacturing and ease of assembly. These blocks contain within them many features and parts many of which are essential to the vehicle. Some of these are the instrumentation spheres, the battery compartment, the main sample collection tunnel, and the wiring harness. As a result we had to have the shaping of the main blocks done with the use of a CNC machine. To do this we found Vectorworks Marine Inc. out of Titusville, FL. Vectorworks has a 5-axis milling machine with over 13 feet of travel made by Thermwood. This machine had the ability to machine any and all of our parts with ease. Vectorworks first started off squaring up all the blocks and beams. Following the squaring of the beams they customized the table to hold the blocks without them sliding. They did this by adhering a disposable foam board down and machining into it then fitting the part into the machined out part. After the part was secured we took our ProE model and programmed in a tool path with the assistance of a production engineer from Vectorworks. Once tested and calibrated we started the tool path on the milling machine and monitored the machining process of the blocks.

4.2.1.3. Side Beams

The Aluminum Side beams were constructed from 4 inch square aluminum beams with a thickness of 1/4 inch. The first step was to cut the beams to length. The beams were cut with a horizontal band saw into two pieces 43 inches long and two pieces 29 inches long. The 43 inch pieces were designed to be in the front and be able to bolt into the main hull of the vehicle, while the 29 inch pieces were designed to be in the rear and carry the servo boxes, ailerons, rudders, and motor mounts. After being cut to length the ends of the beams were squared using the endmill.

A 3-1/2 inch wide corner piece was cut out of the middle of both of the 29 inch long beams for the servo boxes. Within the 3-1/2 inch width of the cut, the cut removed all of the metal of the sides adjacent to the corner being cut out, save the 1/4 inch thickness of the remaining sides. These pieces were cut out using a torch cutter and the edges were cleaned and squared using an endmill.

To make the motor mounts a 1 3/8 inch diameter hole was drilled through the side of each aluminum beam. Then a 4-3/4 inch long 1/4 inch thick aluminum cylinder was placed in each hole so that an inch of each cylinder protruded from each beam and the cylinders were welded into place.

Four connector plates were also constructed in order to connect the two pieces on both sides of the vehicle. These plates were cut to 8 inch by 4 inch dimensions, squared up, and then their edges were beveled. Holes were then drilled into the connector plates and the aluminum beams to bolt the beams together.

All outer facing surfaces of the beams and connector plates were also sanded and polished to remove the oxidation and to shine the surfaces.

4.2.1.4. Bottom Rails

The bottom rails are made from 1 inch diameter 2024 aluminum solid round rods. There are two of these rails, each is composed of five parts. The five parts are the

main horizontal rods, the two vertical legs, and the two mounting plates at the top of the legs.

The horizontal rods were ordered from onlinemetals.com. These rods were first bent in the front using a pipe bender at Mazworx. Then the rods were cut to length so they didn't extend to far out from the vehicle. The legs were then prepared by cutting them to length. Then the legs were trimmed with the end mill so they had a round slot on the end so they would couple with the horizontal rods nicely. Then the mounting plates were made to fit at the top of the legs so the entire rail assembly could be bolted to the beams. The mounting plates were made from some scrap aluminum. The plates were cut to 4 inches by 10 inches. We then drilled four holes in each plate for 3/8 inch bolts. After all of these parts were machined and ready, Bill Bailey from the Florida Tech machine shop welded each of the parts together.

4.2.1.5. *Servo Box*

The Servo Boxes for the glider are two sets of mirrored apparatuses designed to secure the servos for the ailerons and rudders. To do this the box has to both position the servo horns where the rudder and aileron shafts are meant to be and hold the servos onto the beams of the glider.

The construction of the Servo Boxes started with cutting sections out of scrap aluminum beams close to the width of the cut outs on the aluminum side beams using the horizontal ban saw. The vertical ban saw was then used to change the square piece cut into an L piece. Two cuts were made in the sides not being used for the servo boxes using a vertical ban saw. The longer piece created from these cuts then had its edges trimmed to fit into the slot cut in the servo box. Two holes were then drilled into the servo box slightly larger than the servo horn. These holes were centered around where the servo horn is supposed to be. This created one hole on the top front and another in the bottom back. The servo box was then sanded with the following order of grits 220, 400, and 600. After sanding the box was polished using a hand held power drill with

buffing wheel. After the box was polished the tabs to hold the servo were cut out of scrap aluminum. The tabs were two sets of three quarter inch by one and a quarter inch and one and a quarter inch by three and a half inch. These tabs were also sanded with the 220, 400, and 600 grit sandpaper. The tabs were also polished using the hand held drill and buffing wheel. The tabs were then welded having the smaller tab with its largest surface welded on the corner side of each of the holes for the servo horn and the center of the hole aligned with the center of the tab. The other tab was positioned identically to the first tab, but away from the hole it was centered on far enough to allow the servo to be put in between the tabs. After the tabs were welded in place the welds were cleaned up to remove excess material interfering with the servos fitting into the space for them. The servos then had to be secured to the tabs by bolts. To do this we lined up the servo and sighted the two mounting holes on the servo onto the tab. The holes were then drilled out and countersunk. This process was repeated for the other tabs. When we were able to mount the servos the next step was to mount the servo box to the aluminum side beam. To accomplish this we had first drilled the holes for mounting it in the beams. We then lined the servo box up with the slot and marked the 2 holes used to mount the servo box. One of the mounting holes going into the horizontal suspended tab and the other one going through the side of the servo box. The hole in the tab was drilled with a #21 drill bit to allow it to be tapped with a 10-32 tap. The process for created these boxes was carried out at the same time with one box being the mirror image of the other.

4.2.1.6. Ailerons & Rudders

The ailerons and rudders were made in a nearly identical fashion. Both the ailerons and rudders started off in halves that were machined at Vectorworks out of Syntactic foam. As a result the ailerons and rudders will be both rigid and buoyant. The Syntactic foam blocks started off as 2 inches thick and 6 inches wide. They were first machined with a 3/4 inch groove on the bottom followed by the machining of the

foil shape on the reverse side. The shafts were then prepared by welding a small disk on the end with tiny holes for #3 bolts so the shaft could be attached to the servos. Once this disk was welded in place, small flanges were attached to the shaft so the shaft would not slip inside of the ailerons or rudders. Once the shaft was completed it was sandwiched between the two halves of the ailerons and rudders then the two halves were epoxied together. Once cured some filler and epoxy was added to the tip so the ailerons and rudders came to more of a point since the Syntactic foam couldn't be machined that thin. Following some light sanding the ailerons and rudders were covered in three layers of fiberglass to help give them some resilience. After the fiberglass cured we applied sand-able filler to the ailerons and rudders to prepare them for painting at Maaco.

4.2.1.7. Aileron Coupler & Camera Mount

A unique feature of the glider was the central funnel. To optimize the use of this funnel mounting points for lights and a camera would be needed. The mount we designed to satisfy this solves the problem of where to mount the camera in addition to supporting the ailerons.

The construction of the camera mount started with creating all the pieces of the mount. The first piece cut was an aluminum tube with an inside diameter slightly larger than the outside diameter of the aileron shafts. This tube was cut to a four inch section to hold the ends of each aileron shaft. A Plate was then cut slightly wider than the diameter of the tube. This plate had a semicircle cut into one end the diameter of the tube to allow it to be easier to weld to. The plate was then welded to the tube. The 'L' beam pieces were then cut to their desired length. The final part of the camera mount was the mounting piece between the 'L' beams and the plate. To do this we cut a small trapezoidal piece whose diagonal edges would coincide with the positioning of the 'L' beams. The plate/tube assembly was then cut to the desired length for the positioning of the ailerons relative to the main foil. After this cut the trapezoidal plate, two 'L' beams,

and plate/tube assembly were welded together to complete the camera mount assembly. The remaining portion of this assembly involves the bolting of the mount into the main foil.

4.2.1.8. Main Thrusters

The main thrusters did not require much work compared to other aspects of the glider. The main thrusters arrived as fully functional 55 lb thrust trolling motors from Minn-Kota. These motors are already in watertight enclosures with strong yet lightweight carbon fiber mounting shafts. The trolling motors were first tested to confirm they worked and to see how much current they required. After they were tested they were completely disassembled. The trolling motors also came with their own speed controller, which had to be disconnected before using.

The first modification was the trimming of the mounting shaft. This shaft is a strong lightweight tube made from carbon fiber. We measured out the tube then cut it to length with a diamond cutter on a dremel. After cutting the shaft we drilled a small hole in the shaft close to the motor housing. We then used this hole to feed the motor's wires through so the motor would fit in the motor mount. After feeding the wires we placed cotton balls in the tube to make a blockage, then poured in some epoxy on them to form a waterproof bulkhead of epoxy. After the bulkhead cured we drilled a hole in the side of the motor mount and secured a barbed hose fitting with epoxy through it. We then attached clear vinyl tubing to the hose fitting and secured it with a hose clamp. We then placed a barbed fitting on the other end with a removable cap. This system allows us to fill and empty the oil without any hassle. The motors were then secured into the motor mount and bolted in so they couldn't move.

The next part of the main thrusters is the propeller tubes. These tubes were added so that the propellers would be protected. Another added benefit to these tubes is that they increase the propeller efficiency by directing the prop wash in the proper direction. The prop tubes are made with a fiberglass shell with syntactic foam strips

filling the inside. We decided to add these syntactic foam strips for two reasons. First we wanted to increase the rigidity of the tubes so they would not flutter from the turbulent fluid flow off the propeller. Second we found in our initial designs that the center of volume for the vehicle was forward of the center of gravity so adding more volume to the back of the vehicle became necessary. One of the ways we did this was by increasing the thickness of the propeller tubes.

To make each of the propeller tubes we started off cutting two 12" diameter circles out of a sheet of ABS plastic. We then bolted the two disks together using a 4 inch spacer. We then wrapped the circumference of the disks with aluminum foil followed by a coat of PVA to ensure the epoxy wouldn't stick. After the first 3 layers of fiberglass we placed small 4 inch by 3/4 inch by 1/4 inch syntactic foam strips along the circumference of the tube. After these strips were epoxied in place a thick coat of epoxy and 410 microlight sand-able filler were applied to the tubes so they could be sanded and faired round before the final layers of fiberglass were applied. After the tubes were sanded the final three layers of fiberglass were applied. After those only light amounts of the filler was needed to prepare the surface for painting.

4.2.2. Assembly

The assembly of the vehicle was completed in stages and sections. The main sections of the vehicle that were constructed separately are: the main foil hull, buoyancy foam, side beams, bottom rails, servo boxes, ailerons & rudders, camera mount, and main thrusters. Following their construction the main structure of the powered glider was assembled.

The first step in the main structure construction was joining the aluminum side supports with the cross members that give it rigidity. Then both the cross supports and the main beams were then attached to the main foil's fiberglass hull making sure that the load is distributed and not on one point. Following this stage each of the parts were

added and assembled into the vehicle working out away from the main foil leaving the motor assemblies and ailerons for last.

4.3. Budget Finances

4.3.1. Price List

Prototype Estimated Price List			
Part	Vendor	Value	Actual Cost
Syntactic Foam	Syntech Technologies Inc.	\$13,100	\$0 (Donated)
FM-6706 Modeling Foam	General Plastics Inc.	\$1185	\$250 (shipping)
Servos	Hitech RCD Inc	\$690	\$446.69
Minn-Kota Trolling Motors	West Marine Inc.	\$479.98	\$445.98
West System Epoxy + Additives	West Marine Inc.	\$459.31	\$359.24
Extra Epoxy	West Marine Inc.	\$425	\$320
Seven: 4"x 50 yard Fiberglass	U.S Composites	\$172.43	\$172.43
Hardware	Home Depot & Ace		\$700
Tools	Ace, Home Depot, etc		\$750
PIC Microcontrollers	Microchip	\$50	\$0 (samples)
Motors + Wiring, Joysticks	Astro Too	\$300	\$100
Misc Parts			\$600

Table 4.3: Prototype Estimated Price List

4.3.2. Sponsors and Contributors

For any project to be a success you need a certain amount of resources available for the design and construction process. Usually these resources come in the form of money, however that is not always the case. For some companies it is in their interest to donate product to help them in both taxes and publicity.

Considering the tax benefits, an example is if a company donates one thousand dollars then they can deduct one thousand dollars from their taxable assets. On the other hand if a company were to donate two thousand dollars worth of product that only cost them one thousand to make, they get to write off two thousand dollars even though it only cost them one thousand. Companies often use this approach to help them save money on taxes. A company will usually determine how much they want to donate for the fiscal year based on how close they to the next lower tax bracket, the further they are the more they donate.

For other companies the motivation is publicity. When product is donated usually the company gets some sort of public recognition from the recipients. This publicity can get an otherwise unknown name a place in an already crowded field. This publicity will show how the company is supportive of research and development of any kind. The last most important part of the publicity is if a person was deciding between an identical product except one was made by company A and the other by company B. When looking at the products the consumer remembers that company B has been giving donations for research and has been contributing to the society so the consumer gets that product instead of the one made by the profit hording company A.

Our project owes its thanks to several key people, organizations, and companies that have made this project what it is today.

Contributors	
Who	How they contributed
Dr. Stephen Wood	Without Dr. Wood's help this project would haven't ever gotten off the ground so while he might not have personally donated funds he donated his time and experience.
Syntech Technologies Inc.	Contributed to us by working with us on the foam design and by donating the large amounts of deep submergence foam.
General Plastics Inc.	Contributed by donating the FR-6700 aircraft / modeling foam for the machining and molding of the main hull of the glider. This mold will be kept intact for future products of the vehicle.
VectorWorks Marine	Is contributing to us by donating their time, experience, and machinery for the construction and machining of our hull mold and the machining of the syntactic buoyancy foam
Scandia Plastics	Donated product consisting of two four and a quarter diameter tubes that will be used for the sample containers and possibly the vertical thruster duct tube

Table 4.4: Contributors

5. Production Model

5.1. Design

Production AUV Powered Glider Specifications		
Running Properties		
Property	% Running Time	Value
Max Speed (Vmax):	30%	2.0 m/s
Endurance (powered):	10%	15 hours
Endurance (glide):	90%	135 hours
Dimensions		
Property	Value	
Vehicle Width:	62.5 inches (66.5 inches at flares)	
Vehicle Length:	76 inches	
Vehicle Height:	20 inches	

Table 5.1: Production AUV Powered Glider Specifications

5.1.1. Structure

The main structure of the AUV Powered Glider is composed of four main parts. The four main parts of the structure are the aluminum beam, the fiberglass hull, the oil filled housings, and the instrumentation spheres. Each one of these parts are vital to the operation of the AUV Powered Glider and each one requires great care in both their construction and usage.

5.1.1.1. *Aluminum Frame*

The aluminum frame makes up the bulk of the structural support for the glider. The structural support frame consists of two 4" x 4" aluminum beams that are 1/8" thick and made of T6063 aluminum. Attaching these two beams together through the beam is two additional support beams that add rigidity to the overall glider and lightening the load on the fiberglass hull.

The two side support beams themselves are not sealed so they do not have to withstand the pressure. The beams provide the mounting points for several key features of the glider. The motors, ailerons, sample containers, rails and even the main foil are directly mounted to the beams. The beams also contain a joint near the back of the main foil where the two halves of the beam can be unbolted. This allows the glider to be split into smaller sections that make it both easier to store and to transport.

5.1.1.2. *Fiberglass Hull*

The main fiberglass hull is made to the shape of a foil. The hull was constructed using a foam mold that was machined by VectorWorks Marine out of Titusville, FL. The mold was made out of General Plastics 6700 aircraft grade modeling foam that was machined in six parts. The fiberglass hull is mounted directly to the two side support beams as well as the two support cross members that pass through the main foil. The fiberglass hull holds many of the features that are essential to the glider. Contained within the glider is the power supply, instrumentation spheres, syntactic buoyancy foam, trim ailerons, specimen collector, and the weights for both the buoyancy control and to simulate the future sensors.

5.1.1.3. Oil Filled Housings

At depths of 4,000 meters underwater, the water pushes in at a pressure of around 6,000psi. Such a high pressure puts a very high demand on the materials and parts being used. In this case if all the parts were made of materials and material thicknesses that could withstand the high pressure both the weight and the cost would grow exponentially. An efficient solution to this problem is to fill all of the housings with non-conductive oil such as mineral oil, more specifically transformer oil. This oil is usually used in capacitors and transformers. It provides an insulating barrier between power feeds and won't short the circuit like seawater. The housing or part will be assembled inside an oil-filled bucket, minimizing the possibilities of air bubbles. Attached to each housing will be a pressure regulator that transmits the pressure to inside without allowing the water to pass. The equalized pressure will then eliminate any force from the pressure that would normally be exerted onto the housing.

5.1.1.4. Instrumentation Spheres

The AUV Powered Glider uses two 17" glass instrumentation spheres. The spheres used in the production model do not have to be made by the same manufacturer, however they will have to have similar specs. Both of these spheres also need to have pressure release valves for reopening them as well as multiple ports for cables to pass through for wiring. These spheres are the only part of the glider that contains air and is the only part that has to directly withstand the 6,000psi of water pressure pushing in on it. Two example spheres made for this task are the Benthos and Victrovex ones used for the prototype.

The first sphere is made by Benthos Inc, and is model number 2040 -17H. It has a 17" outer diameter and weighs in at 39lbs. This gives the spheres a net buoyancy of 56lbs assuming they are empty. The Benthos sphere has been tested at depths of 6,700

meters. The Benthos sphere is also equipped with two ports for cables to pass through the sphere. (Benthos)

The second sphere is made by Victrovex and is the 17"/14 (standard) model. It also has a 17" outer diameter and weighs in at 38.14 lbs with about 61.13lbs of buoyancy. This sphere is also rated for depths of 6,700 meters. The Victrovex sphere also has three ports for cables and another port for a pressure sensor. (Vetrovex)

5.1.2. Central Electronics

The central electronics package onboard the production model of the AUV will include the same microcontroller setup of the prototype model; however, the human element will be removed and a computer designed to output the same information, that a human would have, to the microcontrollers that already control the AUV. The computer will connect to a wireless network. Following this the AUV will use a client-server model application that will allow someone to update mission criteria, microcontroller programs, and various other AUV functions. After all criteria have been entered the AUV will then be placed in the water and told "GO," which will initiate the computer's control system to take control and perform the mission. All control will solely be placed at the fingertips of the computer, while the customer waits for data.

5.1.2.1. *Control Board*

In the production model of the AUV Powered Glider the control board will most likely be a laptop computer. This is because the AUV will have an onboard computer that will actually perform the maneuvering and mission requirements. The control board/laptop will setup the mission criteria on a nice graphical user interface (GUI), and then basically tell the AUV to "GO."

The communication between the control board/laptop and the AUV will be over a standard wireless connection, using a client server model to issue the mission requirements to the AUV.

5.1.2.2. *Main Computer*

The production model will be equipped with its own onboard computer. The reason for using a full computer instead of a simple microcontroller is that setting up mission requirements will be easier on a standard computer. In addition the various scientific devices and sensors we will hopefully be using may already contain drivers for normal operating systems. Thus, it will be easier to install these devices on a system that requires no further programming to get working.

The computer will use standard PC104 or PC104plus boards for a single board computer and various add on modules. The reason for using this size board is that they have been standardized, and a number of manufacturers already produce boards of that size with stackable systems. This will make installing the computer into the 17-inch glass sphere easier. (Wood)

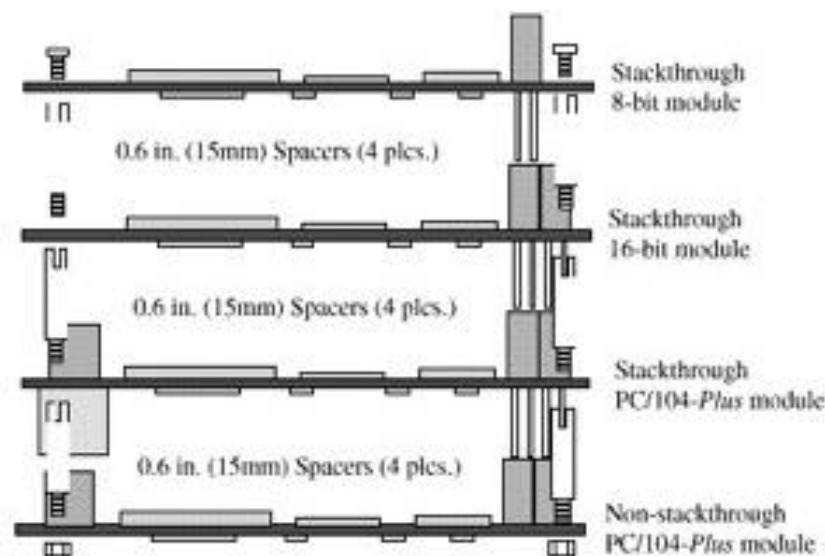


Figure 5.1: PC104 board stack

The main computer will connect into the system built for the prototype configuration in place of the control board. The PIC microcontrollers will still be responsible for the majority of onboard operations, while the main computer will be responsible for the attaining mission objectives and navigation. The main computer will then send the signals that would be coming from the operators I the prototype model to the same microcontrollers used in the prototype.

5.1.2.3. Recovery System

The recovery system on the prototype will be further augmented in the production model. In the production model we will be using a satellite transmitter. When the AUV reaches surface level, it will begin to send pulses to a satellite that will then update its location to the prospective user. This will allow for a direct GPS location updated feed that can be tracked to its exact location. The recovery system on the prototype model will still be used for closer range recovery efforts. Furthermore the satellite transmitter will also be powered by the separate power system in the recovery system.

5.1.2.4. Main Thrusters

The main thrusters are controlled by the glider's computer instead of by an operator. Since, the computer will be controlling all major systems to fulfill mission requirements. The thrusters will also move out of a simple on/off configuration and move to a speed controlled operation. However, this will still require the H-Bridge in the configuration.

5.1.2.5. Servos

The servos on the prototype will basically be the standard by which the production will be designed. The servos should have the durability and reliability to work in the constraints already designed and proposed on the prototype model.

5.1.2.6. Power Management

The power system on the production AUV model will consist of either battery stacks or a hydrogen fuel cell. Both systems will have a high initial cost. The battery system could use rechargeable batteries. Thus, the recharge cycle is the only cost incurred between missions. While the hydrogen fuel cell would require new hydrogen between missions. Both systems would do the job, and not require the tether that will be used in the prototype model.

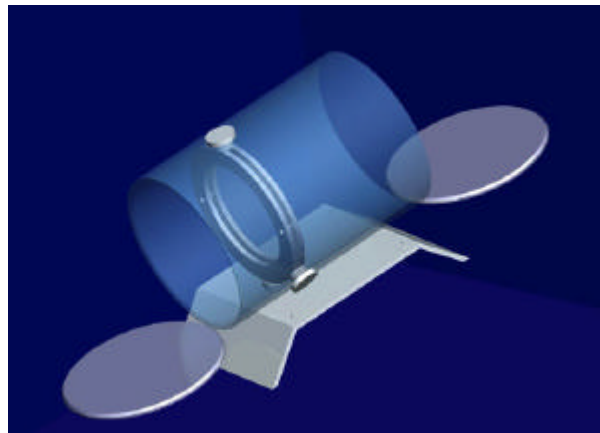
5.1.3. Scientific

The AUV Powered Glider is a scientific research vehicle. The methods for doing scientific research are through its uniquely designed sample containers and through the multitude of instruments, which it can be equipped with. The sample containers are designed for obtaining water or specimen samples as discussed later. The sensors can be divided into two groups: basic sensors and advanced modular sensors. The basic sensors are essentially what the vehicle needs to be equipped with to navigate and survive. The advanced modular sensors are sensors that may or may not be equipped due to the nature of the specific mission.

5.1.3.1. Sample Containers

The sample containers for this AUV Powered Glider are there to allow the researcher to collect both water and small specimen samples from many depths. Unlike the prototype model the number of the containers and there positions are more up to the researcher using the vehicle. The prototype only has space for the four standard ones, but several rectangular sections fifteen inches long and five inches wide could easily be removed from the top and bottom of the main foil to allow for additional containers. In addition to adding these if the researcher was more interested in water samples than collecting specimens a smaller container could be used without the screen only consisting of the doors and tube. The smaller size of these containers could allow for additional containers to be mounted to the beam or smaller sections removed from the main foil, thus allowing more containers to be mounted there also. Even with the variety of containers to be used by the production model each one would still be able to activate separately. The activation of the sample containers would change based on which containers were being used. The containers with the screen would rotate the screen inside from being parallel to the direction of motion to perpendicular to it. After a set amount of time, based on the researcher wants, the two doors would release closing and sealing the containers. To obtain the sample the researcher would then have to remove the container by unhooking the nylon strap holding the container down and pulling the sealed container vertically away from the box. During the removal the researcher would need to be careful so as not to damage the connector from the container to the glider.

The standard containers are made of clear tubing to allow the researcher to view the contents before opening the container. The tubing for each container is four and a quarter inches in diameter, an eighth of an inch thick, and six inches long. The tubes have three six tenths of an



inch diameter holes cut into them, two vertical and one with its axis offset by forty-five degrees. The holes are two inches back from the front of the container. These holes allow for the pivot points and stopper for the rotating screen in each container. Each hole is lined with a rubber seal to allow the container to be watertight. The pivot points and stopper are made of a half-inch diameter aluminum rod that is .95 inches long. The interior portions of the pivot points and stopper have a half-inch by half-inch section removed parallel to the side of the rod going in by .4375 inches. This cut is for the screen to fit into. The top pivot point and stopper have an eighth of an inch thick and three quarters of an inch diameter head on their exterior portion to keep them attached to the tube. The bottom pivot point has an eighth of an inch thick quarter inch square keyed to the connector attached to the servo. The screen is held in place by 2 thin aluminum plates. One plate is mounted to the pivot points and the other is pressed against both the mounted plate and the screen by thumbscrews. The plates are rings with a 3.8 inch outer diameter and 2.8 inch inner diameter. The plates are 3.8 inches to give them room to be able to rotate freely rather than be completely up against the edge of the container. The plates have two eighth of an inch holes cut opposite of each other 1.65 inches from the center of the rings. The screens are replaceable so that a variety of gauges can be used to collect what the researcher is interested in. Each screen has a circular shape that is 3.8 inches in diameter with the top and bottom quarter inch removed. There also are 2 eighth of an inch holes cut into the screen a quarter inch from the left and right edges for the thumbscrews to pass through. The doors to the sample container are eighth of an inch thick aluminum plates and a four-inch diameter including the rubber seal on the door and container. The doors are closed by a spring attached to the tube and outside of the door. Each door is held open before it needs to be deployed by an arm of a servo. The servo holding the door closed is a HS-125MG slim wing servo made by Hitec RCD USA, Inc. The sample containers rest on a trapezoidal platform made an eighth of an inch thick aluminum. The box is one and one eighth inches high, has a four inch long and three and a half inch wide top, the two diagonal pieces extend down at a forty-five degree angle. The top portion of the box has an eighth of an inch diameter hole cut into each of the four corners a quarter of an

inch from each side. These holes are used to bolt the box to the side beams of the aluminum container. There is another hole .6 inches in diameter centered one and three quarters of an inch from the side of the box and one inch from the front of the top portion. This hole is lined with a rubber seal to reduce friction from the rotating connector that goes through it. The connector is made out of the same half-inch diameter aluminum rod as the pivot points and stopper. The connector is 0.225 inches long and has an eighth of an inch deep quarter inch square hole cut in the top to allow the bottom pin of the container to connect to it. The servo this connector is mounted to is a HS-55 standard feather servo made by Hitec RCD USA, Inc. On the bottom of the box is a nylon strap that loops over the sample container to hold it down.

5.1.3.2. Basic Sensor Pack

The basic sensor pack is the group of sensors that should be equipped to the AUV Powered Glider for all missions. The two main functions of this basic sensor pack are navigation and survivability. While many of these sensors can provide useful scientific data as well, such as the CTD, they also ensure that the vehicle is safe and on course.

The basic sensor pack for the production model AUV Powered Glider will consist of a CTD, Object Avoidance SONAR, Bottom Profiling SONAR, and the Inertial Navigation Unit.

The CTD's primary use in the basic sensor pack is that of an altimeter. Its ability to provide an accurate depth of the vehicle will be essential to ensuring that the vehicle does not exceed its maximum depth. Also it will help ensure that the vehicle is in the appropriate level in the water column to complete its mission.

The Object Avoidance SONAR is in the basic sensor pack to be able to detect an object in front of the vehicle that the vehicle is in danger of colliding with. The detection of an object would trigger either the ailerons or the rudders to steer the vehicle around the object depending on the circumstances.

The Bottom Profiling SONAR will be able to tell the vehicle how far the bottom of the ocean is to the bottom of the vehicle. This will be helpful if a mission involves study near an ocean floor, or if the vehicle is diving and the bottom (or an object) is directly below it. Detections such as these would trigger the vehicle to level off at its present depth.

The Inertial Navigation Unit is primarily a navigational tool. It will detect an acceleration of the vehicle in any direction, which can track where the vehicle travels relative to its starting point. The inherent problem with the Inertial Navigation Unit is the error. The error accumulates over a period of time, the longer the vehicle is running off of those sensors the larger the error gets. While it is an extremely useful navigational instrument, it requires that a reference point be provided after a period of use to ensure reasonable accuracy. (Wood)

5.1.3.3. Advanced Modular Sensors

There will be several sensors included with the AUV Powered Glider that are for the sole purpose of collecting scientific data. Since these sensors are not vital to the operation, navigation, or survivability of the vehicle they may be replaced by other sensors of similar size and weight and shape, or they may be entirely left out for certain missions. It should be noted that the scope of scientific sensors that can be employed by this vehicle is by no means limited to these specific instruments.

The sensors included with the prototype AUV Powered Glider as Advanced Modular sensors are the Fluorimeter, the UV VIS Spectrometer, and the Hydrophone Array.

The Fluorimeter will be able to detect the chlorophyll present in living organisms such as phytoplankton. This instrument will be useful for marine biology focused missions to track or document where microorganisms are present.

The UV VIS Spectrometer can identify a chemical by detecting the light absorption properties of the chemical. It can also be used to identify certain chemical

species. This instrument would be useful in either an oceanic chemical focused mission or a marine biology focused mission.

The Hydrophone array is a set of precise underwater microphones, which can detect underwater sounds. These would be useful for missions in many fields, notably acoustics and marine biology.

5.2. Budget and Finances

5.2.1. Consumables

During the lifetime of the AUV Powered Glider there are a few parts that will have to be regularly replaced and updated. Some of these parts might only see a little use and rarely have to be replaced while some other parts might see frequent heavy use and need to be replaced on a regular basis. Some of these parts include rubber seals, transformer oil, mesh screens, weights, buoyancy floats, and batteries.

The rubber seals will most likely need to be replaced on a semi regular basis depending on use. These rubber seals tend to deteriorate when submerged in saltwater and the intense pressure adds additional stress to the progressively fragile seals. The seals around the motor shafts and servos will probably have to be replaced the most often since they are fitted around moving parts that cause wear. While the seals on the sample containers and instrument packs will probably rarely have to be replaced since they just form a seal instead of sealing moving parts.

The transformer oil is the almost incompressible fluid that is used to protect the instruments and parts inside the oil filled housings. These housings will have a small amount of leaking around seals especially as they age and whenever maintenance is done on the parts oil will surely have to be replenished. It is also wise to change the oil in the four motor housings if the thrusters are under relatively heavy use just for extra protection.

The mesh screens will be a very inexpensive item in comparison to the rest of the resources for this kind of vehicle. It is recommended that the screens be replaced for each deployment in order to reduce risk of contamination between studies. The mesh screens also have a tendency to deteriorate quicker than other parts due to how thin they are.

The weights used in the AUV powered glider will need to be replaced for each deployment when the active buoyancy system is used. These weights can be purchased from West Marine and are a relatively inexpensive part to replenish and since the part is mass produced it should be readily available.

The buoyancy floats are made out of Syntech Technology's AM-37 syntactic foam. These floats will need to be replenished after each deployment when the active buoyancy system is used just like the weights. The floats are more expensive than the weights however a design change is being considered for the production model where the floats would have radio beacons so they would yield a higher probability of being recovered.

The final major consumable will be the batteries. Batteries have a tendency to lose their charging capabilities over time. This will happen progressively over a period of time and will be up to the end user to determine when the battery length impedes his ability to conduct his research. Any batteries matching the voltage and continuous amperage requirements can replace the old batteries so if new technology allows for it larger capacity batteries can be used in place of the older ones.

5.2.2. Maintenance

To maintenance that would be needed to be performed on this vehicle would consist of replacing or repairing any damage or malfunctioning pieces of the vehicle. Any damaged component outside of hull parts would have to be replaced. To replace the servos or motors the housing would have to be emptied of their oil and refilled. To do this they would have to be reassembled in the oil leaving no room for air bubbles.

Damage to the fiberglass foil could be patched with excess epoxy and fiberglass. This would maintain the strength of the foil and keep it relatively aerodynamic. Several parts that could be lost and spares would be needed are the bolts holding the motors, servo boxes and main foil together.

Maintenance Supplies		
Part	Model	Price
Aileron/Rudder Servo	Hitech HS-805BB	\$29.99 each
Sample Container Door Servo	Hitech HS-125MG	\$26.99 each
Sample Container Screen Servo	Hitech HS-55	\$10.99 each
Epoxy/Fiberglass	West System Epoxy Resin 105-A	\$29.80 / 1 qt
	West System Epoxy Slow Hardener 206-A	\$13.90 / .44 pt

Table 5.2: Maintenance Supplies

6. Analysis and Testing

The AUV Powered Glider, like every other vehicle or part made, must undergo a series of tests before going into production. The AUV Powered Glider is a new and highly innovative vehicle with most of its parts only known to work out of theory. These theories need to be backed with real world proof.

6.1. Planned Tests

Testing is an expensive and time-consuming phase of the design process. Every part must undergo rigorous testing if it is to withstand the repeated abuse that is sure to happen to any production model in its lifetime. We do have a few planned tests that we feel are essential to confirming the readiness of the glider. These tests will mostly test some of the physical and mechanical aspects of the glider.

6.1.1. Deployment Test

6.1.1.1. Introduction

The AUV Powered Glider is an underwater vehicle being designed to be deployed off the R/V Delphinus. The glider will be an autonomous vehicle capable of being equipped with a variety of scientific sensors. An important part of the design of the glider is to make it able to be safely deployed and recovered by the R/V Delphinus. The goal of this test is to find the best design and method of deploying and recovering the glider. To test various designs and methods a model that is the same size, shape and close to the same center of gravity of the actual glider. The model would have several

‘U’ bolts to test various arrangements of support points for the vehicle to be held with ropes, polls, or winch.

6.1.1.2. *Methods*

The model was built by cutting up pine two by two beams into four seventy six inch beams, three sixty six inch beams, two thirty inch beams at the longest point with forty five degree angle cuts at each end, four fifteen inch beams, one sixty two and half inch beam, and one thirty eight and a half inch beam. The vehicle was the put together by placing the three sixty six inch beams parallel to each other. Between the front two sixty six inch beams place the trapezoidal thirty inch beams so they have one face flush and close to the center of the front beam and the outer edge of the trapezoidal beams touching the second sixty six inch beam. Then lay two seventy six inch beams across the top of the 5 other beams. The positioning of the beams would then need to be adjusted so the front and back sixty six inch beams corners are below the two seventy six inch beams corners. Adjust the diagonal members so that there outer most edge is parallel with the seventy six inch beam on top of it. Make sure the middle sixty six inch beam is still touching the rear most edge of the diagonal beams. Drill quarter inch diameter horizontal holes through the diagonal pieces and the front beam where they meet. Drill quarter inch diameter vertical holes through the seventy six inch beams and the beams below them at every intersection of the beams. Connect the beams together by putting the quarter inch diameter four inch long carriage bolts through each hole and tightening them with a nut. Position the four fifteen inch beams on there end at each corner of the frame. Drill a quarter diameter hole through the fifteen inch beam and seventy six inch beam and another quarter diameter hole through the fifteen inch beam and sixty six each beam, repeat this for each fifteen each beam. Connect the final two seventy six inch beams to the vertical fifteen inch beams by lining them up with the seventy six inch beams below them and the top of the fifteen inch beams. While holding the seventy six inch beams together drill two quarter inch diameter holes through the fifteen inch beams and seventy six inch beams for each seventy six inch

beam on each side. Place carriage bolts through each newly drilled hole and tighten with nut. Mark the distance the center of gravity should be from the front of the actual glider on the bottom most seventy six inch beams, these should be the last two beams attached. The center of gravity is 30 inches back from the front of the model. Place a tube under the model at this mark and apply weights to the front to balance out the glider. We found that the added weight of a sixty two and a half inch and thirty eight and a half inch beam would pull the center of gravity far enough forward. Attach the two extra beams to the front beam by applying gorilla glue to them then clamping the pieces onto each other and allowed to dry for three to six hours. Along the top seventy six inch beams mark the center of gravity again and every inch forward and behind it. Label each hole with a number make sure to label the hole on each individual beam. After labeling the model should be disassembled to be brought onboard.

For the test the model should first be reassembled lining up each numbered hole with its corresponding numbered hole on another beam. Attach two 'U' bolts to the top of the model at the center of gravity line earlier marked and another two along the side of the vehicle. Attach tag lines to each of the other two side mounted 'U' bolts and the wires connected to the hook on the winch and boom to the ones lined up with the center of gravity. Hold the vehicle steady with the tag lines and standoff poll while the model is raised and lowered into the water. Make certain to keep the model from impacting the R/V Delphinus. Note the difficulty in keeping the model from moving while keeping in mind the model is several pounds while the actual glider would be around eight hundred pounds. Repeat this trial for a variety of positions of the 'U' bolts to find the best locations to control the glider while recovering and deploying.

6.1.1.3. Results

The model was deployed with the two points connecting to the winch and found it to be difficult to keep it level. The model would pivot between the two 'U' bolts to lower on end of the model. When the person manning the tag lines compensated for the drop the model would shift to the other side. Although we were able to deploy the

model this way, the actual glider would gain too much moment with it tipping back and forth for a person to be manning the tag lines guiding the glider. The failure of the two point lift method was noticed by the group and the captain. The Captain advised us from his experience deploying and recovering other equipment to use either a single lift point method or a four point lift method. The design of the glider favored the four point method since there were no planned supports going along the top of the glider to position an 'I' bolt at the center of gravity of gravity. The group then loosened and detached the 'U' bolts and repositioned them to create the setup for a four point lifting method. The lines connecting the model to the winch's hook were then tied together. The lines then needed to be adjusted so the force pulling the model up was above where the center of gravity of the model was. This was accomplished by raising the model slightly to determine which lines needed to be adjusted then lowered to allow for enough slack to make the adjustments. After the harness was finished the four point lift was tested. It proved to be much easier to manage with the tag lines than the two point method. When lowering the model a third person with a stand off pole was needed to hold the model away from the transom of the R/V Delphinus.

This test showed us that the four point system worked best. The Captain advised us that for the actual glider the harness used would require a quick release mechanism for safety. The quick release would also allow for a faster deployment of the vehicle by releasing all 4 hooks at the same time. Dr. Kent recommended quick release hooks used in sailing that were designed to hold the lines. These hooks have a pin connected to another line that can be pulled to remove the pin and release the hook. These hooks along with the four point method would be the optimal design and method for deploying the actual glider.

6.1.2. Seals Test

A seals test will test the construction quality and methods just as much as the design of the glider. Getting a perfect seal on various components is extraordinarily

difficult, especially when the component has a moving part passing through the seal or even opens and close on the seal. In this glider there are many parts that will have to be tested for good seals however there are three seals that have the greatest likelihood for failed seals due to the very high machining demands.

The first part that we feel is a trouble spot is where the sample containers open and close. The flaps will be made to fit the opening on the tubes perfectly however with it closing by a hinge and being such a large diameter it's likely the seal can easily be breached. Another part that we have concern for is the seals for the rotating screens inside the sample containers. The servo connection for those introduces a spinning shaft through a seal in a small area so getting a perfect seal will be challenging. The third but not final point to keep an eye on is the shaft for the vertical thrusters. The motors will be relatively high velocity compared to other servos that the seal around them is even more likely to fail.

This test will be conducted in stages. First each of the components will be sealed and held in a situation that will confirm their seal. An example of this will be to fill the sample containers with water and place them with a cloth under them so when you return later you can determine how much water leaked if any. A way to test the vertical thrusters will be to fill their housing with oil and place the thruster directly over a bucket of water in such a way if the seal were to be compromised around the shaft that the oil would drip into the water. The oil would separate from the water in the bucket and become readily noticeable. This test would continue for several hours with intermittent parts with the thruster running.

6.1.3. Operations Test

The operations test would test the mechanical aspects of the AUV Powered Glider. This test is important because it determines whether or not the components made for the AUV Powered Glider are working together or at all. For the test the given

component would be instructed to do one or more actions and then the observer will be able to judge if the part is working properly.

This test is more of an ongoing test than the other ones. This test would be conducted at multiple stages throughout the building of the glider then a final test at the end. An example of this would be to test each servo individually when unpacking to confirm that each is operational and each works the way they are designed to. This same test would also apply to both the vertical thruster motors and the main forward thrusters. It is important to retest each part after working on it so you can confirm that any changes you made didn't adversely affect the components operation. At the end when the vehicle is placed in the water tank or pool for the seals test, this test can also be re-performed in order to check for full operation of the glider. This test would include forward, backward, up, and down motion. The test would also include the rotation of all the sample container screens and the closing of the sample containers.

6.2. Ideal Tests

Some tests require equipment, materials, personal, and time that most projects can't afford. These tests usually don't come in until the prototype model is approved and the final steps are being made towards a production model. These following tests are tests that we would conduct if the resources were available. Each of these tests would also be for the glider during a later stage of development such as after the completion of the main computer.

6.2.1. Software Tests

One test of the software will be the compilation stage. The next test is a visual test of each device out of the water. Basically, the idea would be "Does joystick left equal ruder left?" In this manner any systems that fail can be easily fixed, without too

many issues. After the AUV is in water, then test all systems once more. At this point it is much harder to update the software. And final testing would be to send it on a short mission to a shallow depth. The short duration would allow a more narrow time window of expected arrival, and because it is moving, a narrower area of the water to look for it in. Furthermore, the shallow depth would allow for visual tracking of the AUV, this would allow us to properly test the computer's ability to control the AUV.

6.2.2. Pressure Chamber Test

The pressure chamber test is the best way to test first individual parts then the glider as a whole to see if it can withstand the awesome power of the pressure at 4,000 meters ocean depth. The use of a pressure chamber allows you to recover the glider in the event of a failure in one of the parts. You would then be able to take the part that failed and analyze it to find out why it failed. If this test were to be skipped the first indication to the user that there was a failure would be when it didn't resurface. This test would save a lot of money in the long run despite its high initial cost. This test can cost several thousands of dollars for the use of a pressure chamber for the day as well as the cost of replacing any parts that do break in the process. Despite these high costs, the cost of losing the glider as a whole would be much greater and you wouldn't have the opportunity to learn from the failure.

6.2.3. Long Duration Ocean Test

The long duration ocean test is meant more for testing the AUV powered glider's functionality than anything else. The long duration ocean test is meant to be conducted in relatively shallow water, which we specify as no more than 500 meters preferably even shallower. During this test the AUV computer will be tasked with a series of actions that it needs to carry out. These actions include taking sensor readings and record them, adjusting buoyancy, closing the sample containers, maneuvering with

all ailerons and running all the thrusters. This test will test the glider's ability to operate underwater by itself for a prolonged period of time. This test will require a small to medium sized research vessel in order to deploy the glider however since this test isn't testing deep water the vessel doesn't need to have a very large range.

6.2.4. Short Duration Deepwater Test

The short duration deepwater test is meant for the purpose of testing the structural integrity and the functionality of the AUV powered glider at the design depth.

This test would be conducted by first programming the AUV powered glider to dive to 4,000 meters. Once there the vehicle would release a small set of weights giving it neutral or slightly positive buoyancy. At this depth the AUV powered glider would then test and use all of the servos, motors, and sensors that the glider is equipped with. The AUV powered glider would also run each thruster for several second periods every once in awhile reversing direction and speed in order to fully test the seals and components under pressure.

After only a few hours the AUV powered glider would release one or more of its weights giving the glider positive buoyancy that would push it up to the surface for recovery. At the surface the glider would be programmed to activate its recovery beacon. The glider will then emit its radio beacon as well as flash a bright LED strobe.

6.2.5. Trial Mission

The trial mission would be the final and most comprehensive of the AUV powered glider's tests. The trial mission would consist of a preprogrammed mission like one of the missions described above in section 2.4 "Example Application Scenarios." The glider would be deployed for deepwater operations for extended lengths of time. While deployed, the AUV powered glider would conduct a mission

using all of its available functions. When the AUV powered glider either completed its mission or ran out of energy it would in act its recovery system that would bring it to the surface and signal for its recovery.

7. Liabilities

For matters of liability, or of any question of the operation of the AUV Powered Glider, it will be urged that any user of this vehicle consult the user manual. The manual will clearly warn users against performing any procedure not mentioned in the manual and against using the vehicle in any manner. Many issues will still be addressed in the manual to inform users of the potential hazards and legal matters pertaining to the operation of this vehicle

7.1. Health

The housings for the thrusters and servos will contain mineral oil and may eventually contain transformer oil. It will be recommended to users that eye protection should be worn at all times when working with either of these oils. Users should avoid prolonged or repeated contact with these oils. For prolonged contact with mineral oil or transformer oil for repairing of the housings it is recommended that the user wear non-latex gloves as prolonged contact with either may cause dermatitis. Neither mineral oil nor transformer oil should be ingested, as both may be mild toxins. (Mineral Oil), (Day, L, and R. McGehee)

When working with fiberglass users should always be in a well-ventilated area and wear a mask. Users will also be notified that fumes from epoxy and fiberglass dust are harmful when inhaled.

7.2. Safety

Users will be advised to use caution when working with thrusters. Thrusters have considerable torque and can cause serious injury.

Users will also be advised to take precautions when working with the battery, especially when working near the terminals of the battery. Connecting the terminals will shock and cause serious injury to the user.

7.3. Environmental

It will be urged that if a leak of the mineral oil or transformer oil should occur an effort should be made to contain the oil and minimize the spillage. (Mineral Oil), (Day, L, and R. McGehee)

A take is defined by the MMPA as, “to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal”. If an incidental take of an endangered species or marine mammal is to occur with the AUV, it is required that the user has an incidental take permit under the ESA or the MMPA. (Showalter, 81)

7.4. Legal

Since it is still unclear whether AUVs are considered vessels and some cargo carrying AUVs are already considered AUVs, it is recommended that the user follow the International Regulations for Preventing Collisions at Sea (COLREG). COLREG requires inconspicuous partly submerged vessels to display a white all-round light visible to a minimum of 3 miles. The AUV Powered Glider will be equipped with this and it will be imperative that the user replaces the light when necessary. (Showalter, 80)

8. Conclusion and Recommendations

At this point in time there are many parts of the vehicle that will still have to be tested and analyzed for optimal operations. Everything from vehicle dynamics, vehicle statics, abuse, and ease of use need to be analyzed over and over again.

In terms of vehicle dynamics there are a few areas that need to be analyzed and optimized. The most important area is fluid flow in and around the vehicle. The unique shape and functions of the vehicle produce a very unique fluid flow pattern. As a result it would be quite difficult to compare this vehicle to any vehicle ever made before. Therefore the only solution is to first create a computer model and run it through a series of simulations. Then the next step would be to produce a scale model of the glider and place it in a water tank similar to a wind tunnel where the fluid flow can be observed and measured. Once the affects of the fluids flow can be analyzed perhaps a more streamlined and efficient glider can be produced.

The vehicle statics need to be analyzed in several different aspects. The first aspect and probably most important is part and joint stresses. Each part and joint is designed to take the load and stresses introduced to the vehicle during operation and handling. Despite this history has proven that repeat fluctuations in stress and strain can cause micro-fractures in some of the most critical parts of the vehicle. This instance first showed itself in airplanes when the stress and strain of the flights added cumulative damage to the airplane that ultimately led to a failure despite the materials and parts being well within the threshold required.

Both laborers and end users will handle the AUV powered glider, as a result handling needs to be looked at very closely. While we will know how to properly handle the vehicle that doesn't mean that everyone will. This type of use falls under the category of abuse. This abuse can be introduced in ways it's assembled, moved, deployed, or even stored. The best way to do this is first sit down and make educated guesses on how an inexperienced person would handle the vehicle and make design changes accordingly. The next thing to do would be to make a full-scale replica and use several groups of people, preferably both experienced and inexperienced deck hands.

Then we would set up the replica and ask them to handle and deploy the vehicle without any guidance from us so we can observe what abusive mistakes people are likely to make in the AUV powered glider's handling.

One of the other major aspects of the AUV powered glider that need to be analyzed is the ease of use. This involves everything from ease of assembly, maintenance, programmability, deployment, and collection. Each of these areas as well as others, need to be fully analyzed in terms of the most inexperienced end user. Also stemming from this study will be the manual and any kind of training course of video necessary.

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10. Appendix

10.1. Financial Sheets

10.2. Mold Releasing Agent Lab #1

10.3. Mold Releasing Agent Lab #2

10.4. Model Glider Test Deployment Experiment

10.5. General Plastics Modeling Foam Data Sheet

10.6. Syntech Technologies Syntactic Foam Product Sheet

10.7. Benthos Instrumentation Sphere Data Sheets

10.8. Minn-Kota Trolling Motor Data Sheet

10.9. Hitec Servo Data Sheets